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POLAND

Military

Text of an Article: "The Role and Tasks of the Artillery in Radio-Electronic Counter-Measures"

CONTENTS

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Introduction

1. Radio-electronic counter-measures are not the exclusive domain of any particular branch of the forces; they are employed by all the arms and services which use radio-electronic equipment in their operations, or which can influence (neutralise) similar equipment of the enemy. The artillery has a large share in the whole field of radio-electronic counter-measures, and the present paper is devoted mainly to this aspect of the whole question.

2. In order to discuss in the most comprehensive way the problem of radio-electronic counter-measures which can be performed by the artillery, it will be examined from three points of view;

(a) artillery activities within the framework of radio-electronic counter-measures for the benefit of other arms and services;

(b) artillery activities carried out for its own needs;

(c) the activity of other arms and services for the benefit of the artillery.

3. The only practical way in which the artillery can operate in the field of radio-electronic counter-measures for the benefit of other arms and services is by neutralising (destroying) the enemy radio-electronic devices. When operating for its own benefit, the artillery carries out such actions as reconnaissance, neutralisation by fire and jamming of enemy radio-electronic devices, masking own radio-electronic systems, and protection of own radio-electronic devices from enemy interference. Other arms and services, operating within the framework of radio-electronic counter-measures, carry out for the benefit of the artillery reconnaissance, jamming, and destruction of certain enemy radio-electronic systems and devices.

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I. A general description of enemy radio-electronic devices and the method of engaging them by the artillery

4. The neutralising (jaming, or destruction) of enemy radio-electronic systems and devices, with the simultaneous preservation of the operational capacity of own resources of this type, results, on a modern battle-field, in the achievement of considerable superiority over the enemy and decides to a very great extent the success of the operation. Modern designers are well aware of this fact, and they try to ensure that the resources and equipment devised by them will have provision for multi-channel operation, or will be able to carry out their tasks according to a pre-arranged programme. The employment of all sorts of astro-navigation, inertial, self-homing passive type, and other systems provides one method of solving the difficulty, but such systems can be applied mainly to munitions of a great destructive power, in the employment of which errors of the order of some hundreds or even thousands of metres are of no great consequence.

5. The situation is different on the battle-field itself, particularly in the tactical area. The employment in this case of weapons of great destructive power may not produce the required effect, since, in the majority of cases, it is necessary to secure very accurate hits on specified targets. Such a task may be executed by conventional and rocket artillery using radar devices for directing and correcting their fire, by rocket artillery using guided missiles, and by bomber and fighter-assault [myśliwsko-szturmowe] aircraft guided to ground targets by means of special radio-electronic systems. The number of such devices on a modern battle-field is very large.

6. A separate important group of radio-electronic devices essential in a tactical area is formed by systems and devices used in A.A. defence, the effectiveness of which depends above all on these devices. In addition, the tactical area contains a very large number of all sorts of communications, television and radio-electronic counter-measures equipment.

7. To illustrate the fact, the table below gives the approximate number of various types of radio-electronic devices which may lie within range of our conventional artillery in the zone of operation of an army corps of a U.S. field army. Account was taken primarily of radio-electronic devices of considerable dimensions and great importance.

Table 1

Arm (or service)	Purpose of radio-electronic devices	No. of Devices	Distance from FEBA (kms)
Conventional artillery	Radar sets for reconnoitring the forward edge of the enemy defence, assisting artillery shoots, and detecting the mortars	24-30	2-5
Rocket artillery	"Lacrosse" missile guidance sets	12	1-3
A.A. artillery	Early Warning (tactical control) M-33 artillery radar systems T-38 artillery radar systems	60 8 72	
Detection & guidance systems	Radar detection and guidance sets	6	10-12
Air Force	Radar sets for guiding aircraft to ground targets	3-6	5-15
Signals	Medium-power SW and VHF radio sets Radio relay stations Television systems	to 50 20-25 1-3	10-15 0.3-0.5
Recon-naissance	VHF DF sets Radio-electronic reconnaissance sets	2-4 2-5	5-10 2-3
Counter-measures	VHF communication jamming sets) Radar jamming sets)	up to several dozen	3-10 7-15

8. It is apparent from the above table that the number of enemy radio-electronic devices which can be neutralised by the fire of conventional artillery is very large. The majority of the enemy radio-electronic devices mentioned above have their counterparts in our own equipment, as a result of which their significance, size, and value are

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known and appreciated. It is only necessary to give brief characteristics of such equipment as: the "Lacrosse" missile guidance system, the system for guiding aircraft to ground targets (AN/MSQ-1), and the tactical television system.

9. "Lacrosse" guided missiles are intended for striking single and group targets in the tactical area of defence (up to 20 kms from the FEBA), as part of the direct support given to forces on the battle-field. The range of fire is 8-32 kms; the missile reaches a height of 1800-3800 metres; the accuracy is very good; the average error on impact [blad trafienia] is 5 metres at a range from the guidance set of 1000 metres, and 10 metres at a range of 5000 metres. The missile launchers are deployed not closer than 10 kms from the FEBA, while the guidance equipment is brought up as near as possible to the FEBA. Missile guidance begins at a distance of 250 metres from the launcher, and ends when the missile has travelled about 20 kms from the guidance system. In the initial phase, the missile guidance is automatic, using inertial and later command guidance. The guidance system of the missile consists of the following elements:

(a) Ground elements:-

- radar missile guidance set (angular co-ordinate measurement set);
- electronic computer;
- radar range-finder;
- pulsed light locator, serving for the measurement of the co-ordinates of visible targets;
- power supply.

(b) Mounted on missile:-

- radio beacon, making it possible to measure the angular co-ordinates of missile;
- transponder, co-operating with the ground radar range-finder.

10. The radar angular co-ordinate measuring set ensures the continuous measurement of the co-ordinates by obtaining bearings on the

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radio beacon mounted in the missile. The set operates by the cone selection method, in the azimuth sector of ± 330° and in the angle of elevation sector of -15° ÷ + 87°. The width of the cone of selection in the coarse system (the period of search for the missile) is 24°, and in the fine system (tracking) -2.8°. The set operates on wave-lengths of the order of 1.6-1.8 cms, with a recurrence frequency of 2000 cps. The power of the radio beacon transmitter is 20 kW.

11. The range-finder operates on wave-lengths of the order of 70-100 cms. The ground command transmitter has a power of about 10 W. The width of the directional aerial beam is about 70°.

12. A battalion of "Lacrosse" missiles consists of 4 launchers, which, during the first hour, can ensure the launch of 12 missiles (3 from each launcher)*. An army corps is usually allocated three battalions of these missiles.

13. The AN/MSQ-1 system is intended for guiding the "Matador" guided missiles, and bomber and fighter-bomber aircraft of the tactical air force. The range of the system is about 320 kms. The full complement of the system consists of the following elements:

(a) On the ground:-

- radar set, type AN/MPS-9, for tracking the missile;
- electronic computer, type AN/MSA;
- automatic plotting table [? planszet];
- command transmitter;

(b) Mounted in the missile or aircraft:

- transponder, type AN/APW-11, working with the AN/MPS-9 set, as a result of which a long aircraft or missile tracking range has been achieved;
- command receiver.

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*The occupation of a position which has been prepared from a topographical and field engineering point of view, and the preparation of a single launcher for fire takes about 30 minutes.

14. The AN/MPS-9 radar set has been designed on the basis of the artillery radar set type SCR-584. It operates in the 2700-3100 Mc/s band, with a recurrence frequency of 380-450; two or three-pulse coding groups per second (a suitable spacing of the pulses and their modulation has resulted in a considerable immunity to jamming and a capacity for transmitting the necessary commands). The set operates on the cone selection system [wybieranie stozkowe].

15. The answering device in the missile or aircraft consists of a receiver, transmitter, answering pulses, command and code decoder, and command indicator (in aircraft).

16. The command transmitter operates in the 30-40 Mc/s band, with frequency modulation, and is probably used for the transmission of commands for the dropping of bombs or setting the missile into a dive [pikowanie].

17. The ground guiding post usually consists of 1-2 sets of AN/MSQ-1 systems. In the zone of operation of a U.S. field army there may be up to 6 or 9 such posts.

18. The tactical television system is intended for operation on behalf of the tactical formations. The range of its ground-based TV cameras is, in day-time, about 1.6 kms. Cameras mounted on aircraft extend the visibility to about 8 kms. The ground equipment consists of three observation posts (cameras), which send back pictures through television relays operating on centimetric wave-lengths over a distance of 30-40 kms. The airborne equipment generally consists of two reconnaissance aircraft equipped with TV cameras, which pass the picture to a ground receiving base even at quite a considerable distance.

19. A small television assembly (called 'Creepie-Peepie') consists of a camera making possible observation up to a distance of 1.6 kms, a video transmitter integral with it and operating in the 360-600 Mc/s band, and a receiving device up to 1.5 kms distant from the camera.

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20. Enemy radio-electronic devices, or groups of devices, selected by the Front (army) HQ for engaging with artillery fire, are detailed in the radio-electronic counter-measures plan of the Front (army), in the part concerning the artillery, in a general form (without giving their co-ordinates). The location of targets selected for engagement by the artillery may often be insufficient to determine the firing data. In this case, the staff of the army artillery, within the framework of reconnaissance organised for the purpose of determining the location of all the targets selected for neutralisation by the artillery, issues tasks for the additional reconnaissance of enemy radio-electronic equipment as well. This reconnaissance is usually carried out by optical, air and radio-electronic methods.

22. Optical methods do, it is true, make it possible to determine the co-ordinates of targets with great accuracy, but when the enemy has almost completely camouflaged the positions of radio-electronic devices, the possibility of using optical methods is limited. At night, radio-electronic devices, particularly during the changing of their position, may be observed by infra-red methods.

23. The reconnaissance of enemy radio-electronic devices by the forces of the artillery air force is conducted within the framework of normal reconnaissance work, by means of photography and visual observation. Photographs are usually taken at a scale of 1:3000. During a single sortie of a reconnaissance aircraft, it is possible to reconnoitre 1-3 major radio-electronic installations (radar sets, high and medium-power radio sets etc.).

24. Radio-electronic reconnaissance devices held by artillery units (sub-units) make it possible to detect enemy radio-electronic equipment, to determine its co-ordinates, and - by analysing the signals - to determine the type of the radio-electronic equipment. Artillery reconnaissance devices are usually deployed 1-2 kms from the FEBA of

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defence, at intervals not exceeding $\frac{1}{3}$ the desired range (taking into account the radio horizon). The reconnaissance data are processed in reconnaissance sub-units on special plotting tables [planszet]. The accuracy of these data is not as great as on an air photograph; taking into account the error of the topographical tying-in, the error in the orientation of the radio-electronic reconnaissance device, and even the error arising when making the plot on the table, in practice when the distance of the radio-electronic device being DF-ed amounts up to 5 kms, the incidental error may amount up to 35 metres in direction, and up to 150 metres in range.

25. In order to maintain fire at specified enemy radio-electronic targets, one determines the firing data (the setting of the aiming devices; the range, direction and angle of sight). Depending on the actual situation, one carries out detailed preparation for fire, the switching of the fire to auxiliary targets (actual targets) ranged beforehand, or direct ranging on targets (e.g. by means of a field artillery radar set).

26. The number of projectiles (N) required to neutralise an enemy radio-electronic target (e.g. a radar set) is calculated according to the formula:-

$$N = K \cdot \frac{E_d \cdot E_k}{S_c}$$

where K = fire effectiveness factor (taken, during destruction, as being equal to 0.3);

E_d = average error in range (in metres);

E_k = average error in direction (in metres);

S_c = the area of effective damage with one projectile.

The value S_c varies with different calibres of guns, and is taken to be as given in Table 2.

Table 2

Calibre (mms)	85	100	122	152	160
S_c (sq. metres)	50	55	64	78	85

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27. Table 3 gives the numbers, verified in practice, of projectiles needed for the neutralisation of one field artillery or A.A. artillery radar set by means of 122-mm guns, depending on the method of determining the firing data and the firing range.

Table 3

Method of determining of firing data	Range of fire (in kilometres)			
	4	6	8	10
1. Detailed preparation:				
(a) Co-ordinates from air photograph	160	190	240	330
(b) Co-ordinates determined by observation from aircraft	220	250	310	380(?)
2. Switching fire from auxiliary targets	60	90	150	220
3. Direct ranging with the help of a radar set (co-ordinates from photograph)	100	120	130	150

28. When destroying radar sets, the consumption of projectiles increases two or three-fold.*

29. Depending on the role fulfilled by the individual enemy radio-electronic devices, they should be destroyed at different periods. For instance, during the regrouping of own forces, one should destroy radar sets whose function is to detect moving targets and to reconnoitre the FEBA of defence (or to direct the fire), as soon as they are discovered. Before beginning attacks by own aircraft, or before beginning an operation, one should destroy the maximum number of A.A. artillery radar sets and the early warning and aircraft guidance radar sets. Generally speaking, the time of destruction (neutralisation) of

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*Tables giving full data of the consumption of ammunition for neutralising radar sets, and the method of executing the fire, are contained in the "Artillery Manual: Reconnaissance and Engagement of Enemy Radio-Technical Means", which will be published in 1962.

specified types of radio-electronic devices should be chosen in such a way as to prevent the enemy from re-establishing, before the beginning of our planned operations, specified radio-electronic systems by using the forces and resources of the reserve, or by regrouping from secondary axes.

II. Jamming of enemy radio-electronic devices

30. The direction and execution of radio-electronic counter-measures should be centralised as far as possible. Excessive decentralisation is harmful, since it leads to frequent differences between the various arms and services using radio-electronic devices (mutual interference, prevention of reconnaissance, etc.). However, if the actions and methods of radio-electronic counter-action as a whole contain some action (or method) which is specific to only one arm of service, and if this does not harm the interests of others, then it is worth while to place the burden of its implementation on that particular arm of service. In the case of artillery, this specific action includes the jamming of radar sets which are carrying out detection of artillery (mortar or howitzer) fire positions.

31. The principle of operation of the special mortar-locating radar set consists of tracking a mortar projectile and determining the spatial co-ordinates at a number (at least two) of points on the ascending path of its flight, and then determining the location of the point of origin of this projectile on the basis of the physical rules of ballistic flight, taking into account the weather conditions. Owing to the great accuracy in determining the various co-ordinates after the introduction into the computer of the corrections connected with the prevalent weather conditions, the average error in determining the mortar fire positions does not exceed 10 metres. The determination of a mortar fire position is possible after the firing by the mortar of 2 or 3 projectiles, that is, within a few dozen seconds. The effectiveness of operation of a mortar-locating radar set is dependent on the efficiency of organisation of the co-operation

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of the set with the artillery sub-unit detailed for mortar destruction (this co-operation depends to a large extent on an efficient system of communications).

32. It follows from the above that the prevention of effective operations of mortar-locating radars is one of the principal tasks of the artillery in the sphere of combating enemy radio-electronic devices. The first and principal method of preventing operation of these radars is by their destruction. In order to carry out this task, the artillery commander, through the reconnaissance organs, should issue tasks to his radio-electronic reconnaissance cell for determining the locations of mortar-locating radars. However, as the enemy will not switch on these sets unless it is clearly necessary to do so, he should be skilfully provoked into action. The artillery fire directed at the destruction of these sets must be executed as rapidly as possible, to prevent the enemy from moving the sets to another position.

33. Another method of reducing the effectiveness of a mortar-locating radar is by preventing the enemy from tracking the flight of the projectiles along the ascending path of their flight. This task may be accomplished by masking the moving projectiles by means of intense passive interference. Passive jamming may be used by firing special projectiles (fitted with time-fuzes), filled with metallized fibres. The large number of metallized fibres in a projectile, their dispersion in space by means of an explosive charge, and their slow descent (about 60 metres per minute), together with the limited possibility of differentiating between targets by the enemy radar sets (mainly in azimuth and angle of sight) result in the following:-

(a) the intensity of the jamming, compared with the intensity of the signals reflected from projectiles, is very large and the constant echo suppressor circuits (based on the classic principle of utilisation of the Doppler effect), which might be used in

/mortar-locating

mortar-locating sets, are unable to distinguish the signals reflected from the projectiles from the total mass of signals;

(b) as far as the radar set is concerned, this jamming is in practice continuous, in spite of its being created by a succession of separate explosions of projectiles containing metallized fibres;

(c) the period during which the metallized fibres remain in the air is comparatively great (interference clouds created at a height of 1500 metres will only fall after 15-20 minutes); furthermore the jamming can be renewed from time to time.

34. When planning the creation of this interference, one should nevertheless take into account the existence of one's own sets of the same type, often operating in the same wave-band, and the necessity of protecting from attack the mortar sub-units detailed for creating the interference.

35. For instance, if it is necessary to screen various groupings of mortars, one should above all co-ordinate the deployment of the fire positions of these mortars, and their axes of fire, with the location of own radar sets for locating enemy artillery fire positions. From Figure 1 it is apparent that one's own radar set, located about 2 kms from the FEBA, is not always able to observe the projectiles fired in certain directions from the position 'x', since the intense curtain over the fire positions of our own mortars will form a screen preventing observation in sector 1-2 behind the screen. (Figures 1, 2, 3 and 4 are at the end of the report).

36. The necessary number of projectiles filled with metallized fibres, and of time fuzes, as well as the required axes of fire, can be calculated on the basis of one's own tasks (e.g. battery tasks) and the tactical and technical data of the enemy radar sets. Knowing the maximum and minimum ranges of fire, one can draw the probable paths of the

/projectiles

projectiles (Figure 2) and, knowing the axes of fire, one can determine the width of the area of interference (Figure 3).

37. The places of individual bursts of projectiles containing metallized fibres are determined:-

(a) in width of the area of interference (l) - depending on the azimuthal resolution of the radar set θ, when:

$$l \leqslant D \cdot \theta + 0.5\ d$$

where: θ = width of the radar set beam in azimuth (in thousandths);

d = diameter of the interference cloud (in metres);

D = distance from radar set to the screen (in kilometres);

(b) in depth of the area of interference - depending on the resolution of the radar set in distance; in practice, one should set off the bursts at a distance from each other equal to the diameter of the cloud formed by a single projectile;

(c) in height of the interference area (h) - depending on the resolution of the radar set in the angle of sight, when:

$$h \leqslant D \cdot \gamma + 0.5\ d$$

where: γ = width of the radar beam in the angle of sight (in thousandths).

38. For example, when using projectiles forming interference clouds of a diameter d = 100 metres, and the distance of the enemy radar set from the fire positions of our artillery D = 5 kms, and resolution in azimuth Q = 00-50, and in angle of sight γ = 00-50:

$$l = h \leqslant 5 \cdot 50 + 50 = 300 \text{ metres}$$

39. From the above example it follows that, if the creation of the curtain is begun from the bottom, then it may be made even by means of the same mortars whose fire positions are to be screened, without exposing them in practice to the danger of discovery by enemy radar sets.

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40. It should be pointed out that anti-radar screens employed in order to prevent the enemy from DF-ing may also hinder the work of one's own radar sets of various types. As a result, anti-radar screens should only be produced when they have been included in the plan of radio-electronic counter-measures, confirmed by Headquarters.

41. Apart from the methods described above, one should also examine the possibilities of employing active jamming of the [electrical] noise type, as one of the methods of combating enemy reconnaissance conducted by means of radar sets for the detection of artillery fire positions. The power of the interference transmitter, deployed on the ground and jamming the enemy ground-based radar set tracking the target (in this case, a mortar projectile) in the air, at large angles of sight, can be calculated according to the formula:-

$$P_z G_z = \frac{P_s G_s \cdot A \cdot n \cdot R^4}{4\pi \cdot r^4 \cdot b}$$

where: P_z = power of the transmitter of the interference device;

G_z = directional gain of the aerial of the interference device;

P_s = power of the transmitter of the enemy radar set;

G_s = directional gain of the enemy radar set aerial;

A = effective reflecting area of the projectile;

n = interference factor;

b = level of the side lobes;

R = distance of the enemy radar set from the interference device;

r = distance of the projectile from the enemy radar set.

42. In the above example, the distance between the enemy radar set and the interference set "R" appears to the power of four, and not squared, since the power of the signals received on the ground wave (which is propagated just above the surface of the ground) decreases at the fourth (or even higher) power of the distance.

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43. For instance, if P_s = 250 KW;

G_s = 1200;

r = 5 kms;

A = 0.05 sq. metres;

n = 10 (with powerful interference);

b = 0.01;

R = 10 kms (Figure 4), then:-

$$P_z \cdot G_s = \frac{0.25 \cdot 10^6 \cdot 1.2 \cdot 10^7 \cdot 5 \cdot 10^{-7} \cdot 10^{14}}{12.56 \cdot 5.25 \cdot 10^{14} \cdot 10^{-2}} = 19 \cdot 10^9 W$$

[Field Comment: the indices are doubtful, owing to poor legibility]

44. A jamming set of this potential (even when using a high-gain aerial, e.g. G_z = 2000) would have to have a transmitter of enormous power for continuous operation (P_z = 1 MW). Such a set cannot be built in practice.

45. If the transmitter could be placed higher, so as to ensure direct visibility between the aerials of the enemy radar set and the jamming set, then.-

- $P_z \cdot G_z \approx$ 200 W, if R = 10 kms
- $P_z \cdot G_z \approx$ 5 KW, if R = 50 kms

46. The construction of such a jamming set, or even a better one, is technically possible, but it would have to be installed on an aircraft or helicopter. In view of the fact, however, that it could jam one's own radar sets of different purposes, operating on the same frequency band, the use of such interference should be left to the decision of the Headquarters organising radio-electronic interference in the army.

47. Artillery interests in the sphere of interference with enemy radio-electronic devices may also concern:

/(a)

(a) the systems of radio and radio relay communications in enemy artillery units, and particularly equipment operating between the command posts and the fire positions, and between fire control aircraft or radar sets and the fire positions;

(b) fire control radar sets.

48. Tasks in the sphere of jamming of radio and radio relay communications of the enemy artillery, concerning artillery, will usually be included in the army plan of radio-electronic counter-measures, if the army has a sufficient number of resources. The operational branch of the Army Headquarters should above all take into consideration the jamming of the networks and axes of radio and radio relay communications of the enemy artillery, for example in the opening phase of an offensive operation, during the period of fire preparation. The tasks connected with the jamming of the appropriate networks and axes of enemy radio and radio relay communications are executed by radio counter-measure units placed at the disposal of the army Chief of Signals.

49. The jamming of enemy artillery control radar sets, which are simultaneously used for reconnoitring the FEBA and for detecting troop movements on roads and groupings of technical combat equipment, is of interest, in addition to the artillery, also to other arms.

50. The principal method of interference with the operation of sets of this sort is by means of anti-radar masking*. Measures of this nature are executed by engineer troops (from divisional level upwards), and by the (field) forces themselves, including artillery units, in conformity with the army plan of radio-electronic counter-measures.

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*The principles of anti-radar masking have been discussed in the "Information Bulletin" of the G.S., No. 5/45/60, pp. 89-124.

51. In this case, it is also possible to employ active jamming. Basing oneself on the formula:-

$$P \quad G = \frac{P_s \cdot G_s \cdot A \cdot n \cdot R^4}{4\pi \cdot r \cdot b}$$

which may be applied in conditions of the ground propagation of waves, and assuming the jamming of an enemy radar set of:

P_s= 100 KW and G_s= 10,000,

when A= 100 sq. metres,

n= 10,

b= 100,

r= 5kms, and

R = 10 kms,

one can calculate that the necessary transmitter power and the directional gain of the jamming aerial will be:-

$$P_z \cdot G_z = \frac{1 \cdot 10^5 \cdot 10 \cdot 10^4 \cdot 10^2 \cdot 10 \cdot 10^{14}}{12.56 \cdot 39 \cdot 10^{14} \cdot 10^{-2}} = 600 \text{ W}$$

[Field Comment: indices doubtful].

52. A jamming transmitter of this power can be constructed. It would be even simpler to jam the fire control set by means of jamming transmitters high above the ground (e.g. mounted in an aircraft or helicopter). In both these cases, however, the sub-units jamming enemy radar sets of this type are subordinated to other arms, and in order to co-ordinate their operation, the tasks of these sub-units should be included in the overall army plan of radio-electronic counter-measures.

III. The protection of own radio-electronic devices from enemy counter-measures

53. The problem of protecting own radio-electronic devices from enemy counter-measures may be divided into three principal questions:

(a) hindering or preventing the enemy from reconnoitring our own radio-electronic systems and devices by their suitable masking;

(b)

(b) hindering the enemy from jamming our own radio-electronic devices by suitable technical adaptation (using anti-interference devices), or by carrying out special tactical and organisational measures;

(c) destruction of radio-electronic reconnaissance and jamming equipment.

54. The phrase "masking of radio-electronic systems" means action aiming at hindering or preventing the enemy from obtaining from intercepted radio signals (emitted by various types of radio-electronic devices) of data on the purpose, location and capabilities of radio-electronic equipment, and on the grouping and organisation of units using this equipment.

55. Modern means of detection of radio-electronic devices make it possible to make accurate measurements of the principal parameters of radio-electronic devices, which are sufficient to draw up plans for special transmitters or other jamming devices. The accuracy of determination of the location of radio-electronic devices makes it also possible to destroy them be means of fire weapons. One should also constantly remember that the aerials of the majority of radio-electronic devices are permanently connected to the basic sections of the apparatus, and that frequently aerial and transmitting assemblies form an organic whole, which facilitates their detection and destruction.

56. In this situation, the preservation in secrecy of certain of the parameters of the radio-electronic devices may be of decisive importance for the conduct of battle operations. The unhampered operation of some device over a period of some months, days or even hours, is often of great importance, since the enemy cannot be prepared for every eventuality; depending on the degree of surprise, he will be obliged in this case to devote more or less time to the modification of existing, or the preparation and use of new, methods of counter-action.

/57.

57. In peace-time, the masking of artillery radio-electronic systems may be based on the principles of:

(a) masking the whole of certain of the systems, if the purpose of the masking is to conceal the fact of the existence of a certain system;

(b) masking the capabilities of certain systems or devices.

58. In the first case, the radio-electronic devices may operate only in specially-protected areas, which have been examined from the CE point of view, when there is the certainty that within the radius of at least 180° of direct visibility there are no enemy radio-electronic reconnaissance devices, and no strange or unidentified aircraft.

59. In the second case, one resorts to limiting the operation of the systems or radio-electronic devices in time and space (the operation takes place in appointed sectors), forbidding retuning (which deceives the enemy as regards the frequency range), or forbidding rapid retuning of the devices (which gives the impression that the devices have smaller capabilities). During training, manoeuvres, or exercises, one should aim at such an organisation of the work of the radio-electronic devices as to render as difficult as possible the resolving of the radio-electronic system of protection of the forces. In this case, the operators are given only the necessary minimum of tactical and technical data on the equipment. In addition, one should ensure the strict observance of radio traffic discipline and limit the use of radio communications during certain periods of the exercises.

60. In war-time, in addition to such measures as various ways of limiting the operations and concealment of the capabilities of radio-electronic devices, (of course within permissible limits), one should make wide use of various methods of masking against visual observation, and of deception methods, in accordance with the operational masking plan (imitation, simulation and even prompting by agents).

61. When discussing the question of hindering the enemy from jamming our own radio-electronic devices, one should mention that detailed regulations for the organisation of combat operation of radio-electronic devices and systems in conditions of interference are contained in the appropriate instructions. It is worth-while, on the other hand, to draw the attention of readers to methods peculiar to the artillery of tactical counter-interference, since their employment is influenced to a greater extent by commanding officers than by technician-officers operating the devices concerned. In the sphere of radar, these methods include:-

(a) the briefest possible periods of operation of radar sets (this is particularly important in the case of fire control sets, which are very sensitive to interference); for instance, the period of operation of radar sets examining the terrain may be shortened by employing automatic photography of indicators);

(b) hindering the jamming of radar sets in the side lobes of the electromagnetic wave beam; this particularly affects the artillery detection radar sets, which should be placed behind natural cover, which gives screening angles [katy zakrycia] of the maximum permissible size for these sets and for their specific tasks;

(c) deliberate refusal to switch off the jammed sets immediately after discovering the jamming, thus causing the enemy to become convinced of the smallness of the effect of his jamming; simultaneously by reducing the receiver sensitivity, one should accurately DF the sources of the interference;

(d) the working, during the period of preparation of the operation, of the smallest possible number of radar sets, without altering their position, thus creating the impression that the forces are poorly equipped with radio-electronic devices;

4(e)

(e) checking the auxiliary positions exclusively by optical and topographical methods.

62. In the field of communications, such a specific measure may be, for instance, the method of co-operation with artillery fire control aircraft. In this case, one can hinder the jamming by working by means of very short signals, if possible without using call-signs, and by a frequent change of wave-length.

63. The question of using one's own anti-interference systems affects above all the organs which lay down in detail the tactical and technical requirements concerning new equipment, and the designers; for this reason, it will not be discussed here. The question of destruction as a first priority of equipment jamming the operation of our own radio-electronic devices also does not require any additional explanation. One should only a add that the sequence of destruction of enemy radio-electronic devices is laid down by the operational side of the army (Front) Headquarters.

IV. The reconnaissance of enemy radio-electronic systems

64. The problem of reconnaissance of enemy radio-electronic systems and devices is of interest to the artillery primarily from the point of view of the extent and range of the reconnaissance and the selection of its executors.

65. The favourable features of reconnaissance of enemy radio-electronic systems by means of our radio-electronic devices are: considerable depth, secrecy of operation, speed of reception of data, continuity and independence of weather conditions.

66. Radio communications organised in units (sub-units) of enemy artillery on ultra-short waves may be reconnoitred (determination of the parameters, purpose and location of the radio sets, and thereby the grouping) in practice to a depth of 30-40 kms, of course only at those times when the communications are in operation. Examining the problem from the technical point of view, one may state that the parameters of

/enemy

enemy radio sets, and their location, as determined through reconnaissance, are sufficiently accurate for selecting the required type, intensity, and method of jamming. Of least accuracy are the measurements of the co-ordinates of the location of radio sets, since the VHF DF instruments produce readings the accuracy of which is no greater than $\pm 1^{\circ}$. This magnitude of angular error means that the linear error of a group (2-3) of DF instruments varies within limits of 3% of the distance between the DF instruments and the enemy radio set.

67. Among enemy radar equipment, of particular interest to the artillery are the data concerning the parameters and deployment of artillery detection and fire correction radar. The DF-ing and pin-pointing of radar artillery detection sets is particularly difficult in cases when the enemy conceals them behind woods or buildings, which make it impossible to intercept the emitted signals by ground reconnaissance equipment. If the direct path of the electro-magnetic waves between the artillery detection set and the reconnaissance equipment is not obstructed (reflection or complete damping of the wave energy), then the identification of the artillery detection set is possible not only in the main lobe of the radar beam, but also in the side lobes. Proof of this can be seen in the formula:-

$$D_{max} = \frac{\lambda}{4\pi} \sqrt{\frac{P_{RLS} \cdot G_{RLS} \cdot G_{rozp} \cdot b}{P_{min\ rozp}}}$$

where: D_{max} = range of the reconnaissance, without taking into account the curvature of the earth;

λ = wavelength;

P_{RLS} = pulse power of the radar set [RLS]

G_{RLS} = directional gain of the radar aerial;

G_{rozp} = directional gain of the recce set aerial;

$P_{min\ rozp}$ = sensitivity of the recce set;

b = level of the side lobes.

68. It follows from the above formula that a reconnaissance set of a sensitivity of 10^{-7} W, and an aerial gain $G_{rcap} \approx 10$, ensures the detection and measurement of the parameters of sets up to 150 kms distant from the reconnaissance set. This distance greatly exceeds the range of the radio horizon, which limits the depth of the reconnaissance to some d dozens of kilometres.

69. The accuracy of the DF bearings taken with the help of radio-electronic reconnaissance equipment varies between $\pm 1^{\circ}$ and $\pm 5^{\circ}$, which means that if the target being DF-ed is situated 8-10 kms from the identification set, the linear error will be $\pm$ 100 to 500 metres.

70. In the case when the reconnaissance of artillery detection radar is impossible to carry out from the ground, radio-electronic reconnaissance units perform this task from the air. The data on the location of the enemy set are, however, less accurate in this form of reconnaissance, on account of the smaller accuracy of the DF-ing done with airborne equipment. Nevertheless, they are sufficient to organise the jamming of these sets.

71. The acquisition of data concerning radar sets used for ground reconnaissance does not present any special difficulties to the radio-electronic system reconnaissance units, by reason of the fact that such sets are usually set up on rising ground.

72. The reconnaissance of enemy radio-electronic systems and resources is carried out, at army level, by special reconnaissance units, namely a radio reconnaissance sub-unit, and a radar system (radio navigation, rocket missile guidance systems, etc.) reconnaissance sub-unit.

73. Keeping in touch with the arms and services concerned, and the passing to them of (radio-electronic) reconnaissance data, is the task of the radio-electronic system reconnaissance branch (unit) of the reconnaissance unit (Headquarters) of the army (Front) Headquarters. In certain cases the information may be passed on direct by the reconnaissance unit.

/74.

74. The destruction by the artillery of the appropriate enemy radio-electronic equipment brings in its train the necessity for the good co-ordination of the work of radio-electronic system reconnaissance sub-units with the artillery radio-electronic reconnaissance sub-units, and within the framework of the Headquarters of artillery units (sub-units). Such co-ordination is essential on account of the difficulty of simultaneous or immediate maintenance of fire against a large number of targets, which, in the event of the artillery carrying out its tasks over a considerable period of time, may alter their location. Before opening fire by artillery one should therefore check whether a particular target is still situated in the previously discovered position.

75. As far as the checking of the location of enemy radio communications equipment is concerned, bearing in mind the number within the range of artillery fire, the difficulties in organising DF-ing (the DF sets being located at considerable distances from one another), and the necessity of maintaining a continuous control over the frequency spectrum used for communications purposes by the monitoring centres of the reconnaissance units, it is worth while to organise co-operation between radio reconnaissance units and the artillery. The co-operation consists of detailing to reconnaissance units of liaison officers from artillery units, [equipped?] with means of communication.

76. It is a different matter, however, in the case of checking the location of equipment forming part of various systems of radar, radio navigation, rocket missile guidance, etc. The great majority of such enemy equipment, which it is possible to detect and DF from the ground, is located within range of conventional artillery. The detection and DF-ing of this equipment (from the ground) is the task of special companies and groups of the radar system reconnaissance sub-unit. Such groups have a manoeuvrable character and, on account of the limitation of the range of reconnaissance by the radio horizon, they are not always able to

/maintain

maintain a continuous control over the whole frequency spectrum. In this situation, it is completely justifiable to equip artillery reconnaissance sub-units with reconnaissance equipment used for checking the location of enemy radio-electronic targets and for determining their purpose. Reconnaissance equipment of this type may consist of equipment of type RPS (RPS-1, RPS-2, PPS-3).

* * * * *

77. The entire activity of the artillery in the sphere of radio-electronic counter-measures should be based on the directives and tasks contained in the plan of radio-electronic counter-measures of the army (Front). This plan is prepared by the radio-electronic counter-measures branch (unit) of the operational unit (Headquarters) of the army (Front) Headquarters, with the co-operation of Chiefs (Deputies) of radio-electronic counter-measures (and reconnaissance) cells of all the arms and services concerned. On behalf of the artillery, an authorised officer, trained in questions concerning radio-electronic counter-measures, insofar as they concern the artillery, should take part in the preparation of a plan of radio-electronic counter-measures.

78. In artillery, and particularly mortar, units (sub-units), it would appear advisable to train at least 1-2 officers in this subject, and to appoint from among them unestablished Deputy Commanders for matters concerning radio-electronic counter-measures.

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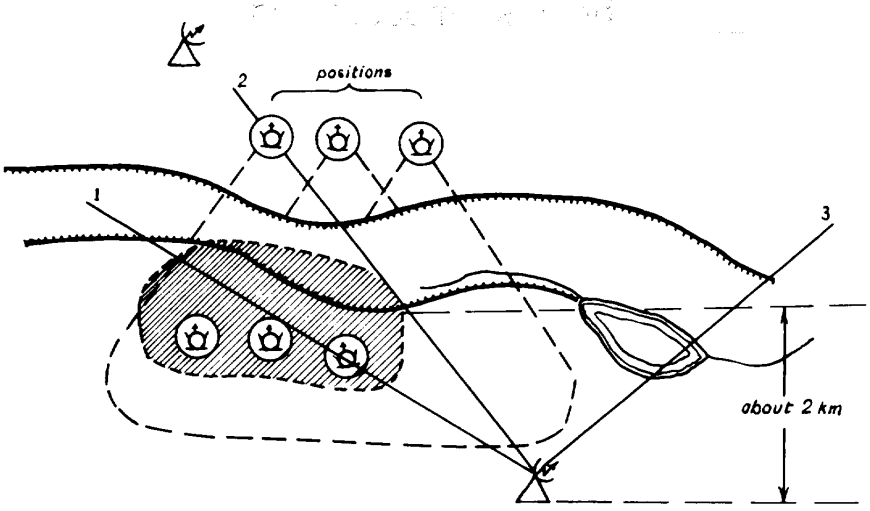

Fig. 1

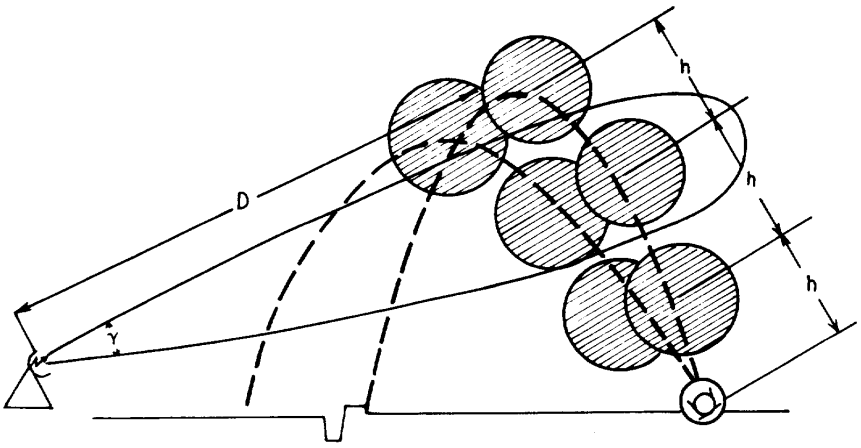

Fig. 2

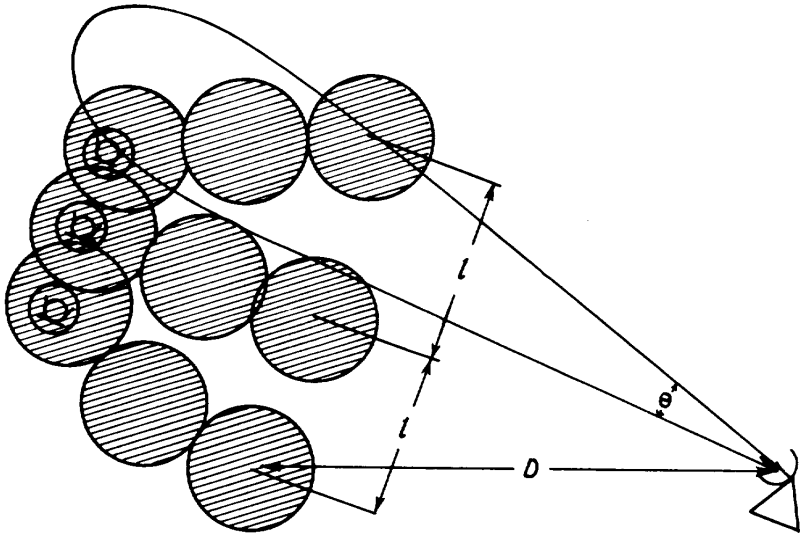

Fig. 3

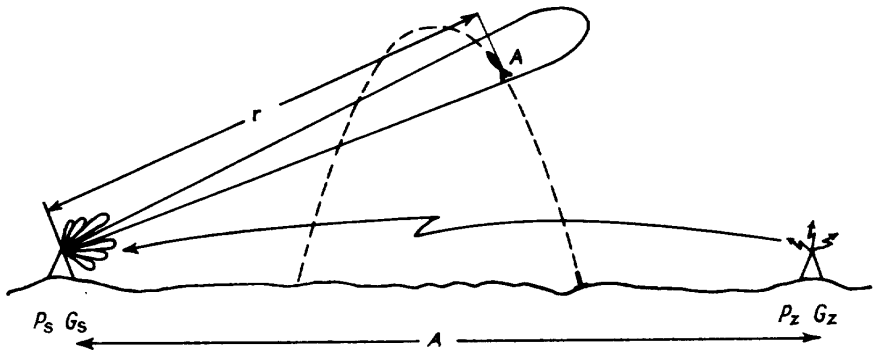

Fig. 4